A NEW SUGAR-AIR BATTERY USING ELECTROCATALYTIC OXIDATION OF SUGARS AT METAL ELECTRODES

Isao Taniguchi, Tesshu Koga, Makoto Nakayama and Tadashi Sotomura*

Department of Applied Chemistry and Biochemistry, Faculty of Engineering, Kumamoto University 2-39-1, Kurokami, Kumamoto 860-8555, Japan
Battery Research & Development Center, Matsushita Electric Ind. Co., Ltd. Yagumonaka-machi, Moriguchi, Osaka 570-8501, Japan

Oxidation of sugars is interesting in various aspects such as waste water treatment in food industry, sensing blood sugar content in medical sciences, and energy conversion in fuel cells. We have reported the results on electrochemical oxidation of sugars at various metal electrodes [1]: The main electrolysis products were found to be formic acid and CO_2 (C_1 molecules), oxalic acid (($COOH)_2$) and glycolic acid ($HOCH_2COOH$, C_2 molecules). Copper electrode was effective for the C-C bind cleavage of sugars in an alkaline solution. Formic acid ($HCOOH$) was a main product for the oxidation of glucose. Oxidation current efficiency of glucose on other metal electrodes than copper were, for example, 70% on Ni, 50% on Au and 35% on Fe. In the present study, we have tried to prepare a sugar-air battery using electrocatalytic oxidation of sugars on metal electrodes.

Although copper electrodes showed catalytic activity for oxidation of sugars, oxidation peak potentials on copper electrode in 0.1 M NaOH solution, measured by cyclic voltammetry, were still rather positive: ca. +0.6 V (vs. Ag/AgCl) for monosaccharides, +0.7 V for di- and trisaccharides and +0.8 V for polysaccharide. These oxidation potential are too positive to make a sugar-air battery, because reduction of dioxygen (air) at a platinum electrode (best electrode for dioxygen reduction) takes place at ca, -0.2 V (vs. Ag/AgCl) in an alkaline (e.g. 0.1 M KOH) solution. Oxidation of glucose at negative potentials was very slow and less effective (see Fig. 1 and Table 1). Similar results we also observed at Ni, Au, and Fe electrodes.

To increase the oxidation currents of sugars at negative potentials on a copper electrode, we have enlarge the surface area of the electrode by various means (roughen the surface by oxidation-reduction cycles, copper plating on the rough Pt-black surfaces etc.). It was effective to some extent, but still more efforts were required to shift the oxidation potential of sugars more negative and enlarge the oxidation current of sugars at negative potentials.

On the other hand, on a platinum oxidation of glucose at –0.3 V (vs. Ag/AgCl) gave mainly glycolic acid (65% in current efficiency) as shown in Fig.1 and Table 1. In addition other mono-, di-, tri-, and polysaccharides were also oxidized on a platinum electrode at very negative potentials such as –0.3 V (vs. Ag/AgCl). On this basis, a battery composed of Pt / sugars in alkaline solution // di-oxygen (or air) in alkaline solution / Pt was prepared and current-voltage curves were obtained (Fig. 2). Using Pt plate electrodes (ca.30 cm^2) for both anode and cathode, the maximum current of 1.5 mA and the maximum voltage of 0.92 V and the

maximum power of 18 $\mu W/cm^2$ (at 0.6 V and 0.92 mA) were obtained (see Fig. 3) using for example a cell of: Pt / 0.1 M Glucose or Galactose in 0.1 M NaOH // Sat. O_2 in 0.1 M NaOH / Pt.
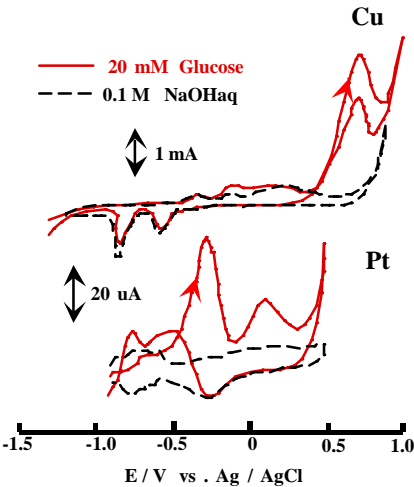

Fig. 1 CVs of 20 mM glucose at Cu and Pt electrodes in a 0.1 M NaOH solution. Scan rate : 50 mV / s.

Table 1. Current efficiencies for formic acid, oxalic acid and glycolic acid by the electrocatalytic oxidation of glucose at Cu and Pt electrodes in a 0.1 M NaOH solution.

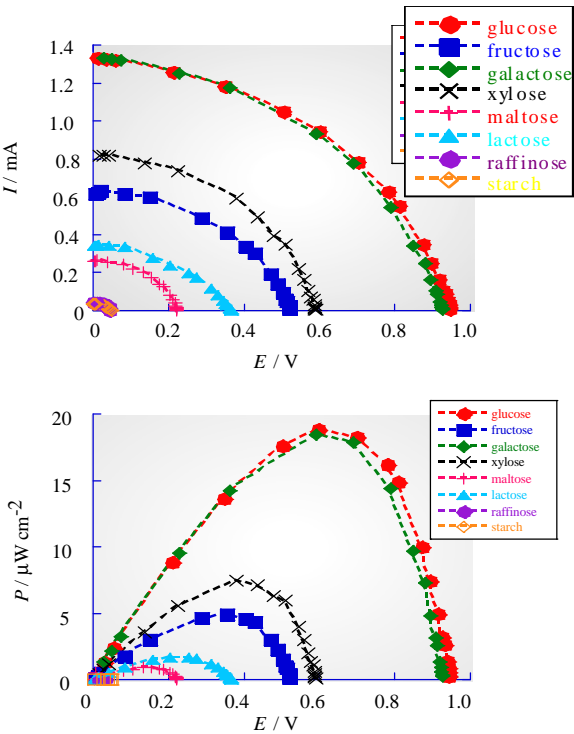|	Electrolysis potential E/V (vs. Ag/AgCl)	Current Efficiency		
		$HCOOH$	$HOCH_2COOH$	$(COOH)_2$
Cu	0.6	97%	30%	4%
	-0.1	21%	19%	3%
Pt	0.6	43%	22%	14%
	-0.3	11%	65%	6%

Fig. 3. (upper) Curent-Voltage and (lower) Power-Voltage curves for a cell of: Pt / 0.1M Sugar in 0.1 M NaOH // O_2 in 0.1 M NaoH/ Pt.

1) I. Taniguchi et al., Abs. Nos. 266 and 267, 189th ECS Meeting; Abs. No 35, 196th ECS Meeting etc.